

Package ‘mtsdi’

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Title Multivariate Time Series Data Imputation

Description This is an EM algorithm based method for imputation of missing values in multivariate normal time series. The imputation algorithm accounts for both spatial and temporal correlation structures. Temporal patterns can be modeled using an ARIMA(p,d,q), optionally with seasonal components, a non-parametric cubic spline or generalized additive models with exogenous covariates. This algorithm is specially tailored for climate data with missing measurements from several monitors along a given region.

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NeedsCompilation no

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`edaprep`*Dataset Preparation for Analysis*

Description

Prepare the dataset for exploratory data analysis

Usage

```
edaprep(dataset)
```

Arguments

`dataset` dataset with missing observations

Details

It replaces missing observation with the vector mean.

Value

It returns `dataset` filled in with NA

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#), [getmean](#), [edaprep](#)

Examples

```
data(miss)
c <- edaprep(miss)
```

elapsedtime	<i>Elapsed Time</i>
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Description

Compute the elapsed time between start time and end time

Usage

```
elapsedtime(st, et)
```

Arguments

st	starting time
et	ending time

Details

It returns the time the process took to run.

Value

String of the form hh:mm:ss

Note

It is not intended to be called directly.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mninput](#)

getmean

*Row Means Estimates***Description**

Estimate the row mean from a `mtsdi` object regarding a fixed number of imputed values

Usage

```
getmean(object, weighted=TRUE, mincol=1, maxconsec=3)
```

Arguments

<code>object</code>	imputation object
<code>weighted</code>	If TRUE, weights returned by <code>mnimput</code> will be used form mean computation
<code>mincol</code>	integer for the minimum number of valid values by row
<code>maxconsec</code>	integer for the maximum number of consecutive missing values in a column

Details

It is useful just in case one wants row mean estimated. If log tranformation was used, mean is adjusted accordingly.

Value

A vector of of rows mean with length `n`, where `n` is the number of observations.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#), [getmean](#), [edaprep](#)

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
m <- getmean(i,2)
```

miss

Sample Dataset

Description

A small sample dataset for the tutorial on data imputation

Usage

```
data(miss)
```

Format

A data frame with 24 observations on the following 5 variables.

c31 a numeric vector with 1 missing observation

c32 a numeric vector with 1 missing observation

c33 a numeric vector with 6 missing observations

c34 a numeric vector with 3 missing observations

c35 a numeric vector with 3 missing observations

Examples

```
data(miss)
```

mkjnw

Example from Johnson and Wichern's Book

Description

Create a data matrix from the Johnson and Wichern's book

Usage

```
mkjnw()
```

Details

This function creates a data matrix from the Johnson & Wichern's book.

Value

It returns a data matrix.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

See Also

[mnimput](#)

Examples

```
d <- mkjnw()
```

mnimput

Multivariate Normal Imputation

Description

Perform the modified EM algorithm imputation on a normal multivariate dataset

Usage

```
mnimput(formula, dataset, by = NULL, log = FALSE, log.offset = 1,
eps = 1e-3, maxit = 1e2, ts = TRUE, method = "spline",
sp.control = list(df = NULL, weights = NULL), ar.control =
list(order = NULL, period = NULL), ga.control = list(formula,
weights = NULL), f.eps = 1e-6, f.maxit = 1e3, ga.bf.eps = 1e-6,
ga.bf.maxit = 1e3, verbose = FALSE, digits = getOption("digits"))
```

Arguments

formula	formula indicating the missing data frame, for instance, ~X1+X2+X3+...+Xp
dataset	data with missing values to be imputed
by	factor for variance windows. Default is NULL for a single variance matrix
log	logical. If TRUE data will be transformed into log scale. Default is FALSE
log.offset	If log is TRUE, log values will be shifted by this offset. Default is 1
eps	stop criterion
maxit	maximum number of iterations
ts	logical. TRUE if is time series
method	method for univariate time series filtering. It may be smooth, gam or arima. See Details
sp.control	list for Spline smooth control. See Details

<code>ar.control</code>	list for ARIMA fitting control. See Details
<code>ga.control</code>	list for GAM fitting control. See Details
<code>f.eps</code>	convergence criterion for the ARIMA filter. See arima
<code>f.maxit</code>	maximum number of iterations for the ARIMA filter. See arima
<code>ga.bf.eps</code>	convergence criterion for the backfitting algorithm of GAM models. See gam
<code>ga.bf.maxit</code>	maximum number of iterations for the backfitting algorithm of GAM models. See gam
<code>verbose</code>	if TRUE convergence information on each iteration is printed. Default is FALSE
<code>digits</code>	an integer indicating the decimal places. If not supplied, it is taken from options

Details

This is a modified version of the EM algorithm for imputation of missing values. It is also applicable to time series data. When it is explicated the time series attribute through the argument `ts`, missing values are estimated accounting for both correlation between time series and time structure of the series itself. Several filters can be used for prediction of the mean vector in the E-step.

One can select the method for the univariate time series filtering by the argument `method`. The default method is "spline". In this case a smooth spline is fitted to each of the time series at each iteration. Some parameters can be passed to [smooth.spline](#) through `sm.control`. `df` is a vector as long as the number of columns in dataset holding fixed degrees of freedom of the splines. If NULL, the degrees of freedom of each spline are chosen by cross-validation. If `df` has length 1, this values is recycled for all the covariates. `weights` must be a matrix of the same size of dataset with the weights for [smooth.spline](#). If NULL, all the observations will have weights equal to 1.

Other possibility for time series filtering is to fitting an ARIMA model for each of the time series by setting `method` to "arima". The ARIMA models must be identified before using this function, nonetheless. [arima](#) function can be partially controlled through `ar.control`. Each column of order must hold the corresponding (p, d, q) parameters for each univariate time series if `period` is NULL. If `period` is not NULL, order must also hold the multiplicative seasonality parameters, so each column of order takes the form (p, d, q, P, D, Q) . `period` is the multiplicative seasonality period. `f.eps` and `f.maxit` control de convergence of the ARIMA fitting algorithm. Convergence problems due non stationarity may arise when using this option.

Last but not least, a very interesting approach to modelling temporal patterns is using a full fledged regression model. It is possible to use generalised additive (or linear) models with exogenous variates to proper filtering of time patterns. One must set `method` to `gam` and supply a vector of formulas in `ga.control`. One must supply one formula for each covariate. Using covariates that are part of the formula of the imputation model may yield some colinearity among the variates. See [gam](#) and [glm](#) for details. In order to use regression models for the level, set `method` to "gam"

Simulations have shown that the algorithm is stable and yields good results on imputation of normal data.

Value

The function returns an object of class `mtsdi` containing

<code>call</code>	function call
<code>dataset</code>	imputed dataset

muhat	estimated mean vector
sigmahat	estimated covariance matrix
missings	vector holding the number of missing values on each row
iterations	number of iterations until convergence or reach maxit
convergence	convergence value. See Details
converged	a logical indicating if the algorithm converged
time	elapsed time of the process

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

- Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. *Atmospheric Environment*, 102, 96-104.
- Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.
- McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.
- Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.
- Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also

[mnimput](#), [predict.mtsdi](#), [edaprep](#)

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
## one-window covariance
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(i)

## two-window covariances
b<-c(rep("year1",12),rep("year2",12))
ii <- mnimput(f,miss,by=b,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(ii)
```

`mstats`*Missing Dataset Statistics*

Description

Carry out some statistics from the incomplete dataset

Usage

```
mstats(dataset)
```

Arguments

<code>dataset</code>	dataset with missing for description
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Details

This function computes the proportion of missing observations in a given dataset by rows and columns.

Value

A list containing

<code>rows</code>	number of missing in each row
<code>columns</code>	number of missing in each column
<code>pattern</code>	the pattern of the missing values

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#), [getmean](#), [edaprep](#)

Examples

```
data(miss)
mstats(miss)
```

plot.mtsdi

*Plot the Imputed Matrix***Description**

This function produces a plot with imputed values and the estimated level for each of the columns in the imputed matrix.

Usage

```
## S3 method for class 'mtsdi'
plot(x, vars = "all", overlay = TRUE, level = TRUE,
     points = FALSE, leg.loc = "topright", horiz = FALSE, at.once = FALSE, ...)
```

Arguments

x	an object of the class mtsdi
vars	a vector with de variables to plot
overlay	logical. If TRUE, observed values are plot over the imputed ones
level	logical. If TRUE, the level is plot
points	logical. If TRUE, points on the observed and imputed values are plot
leg.loc	a list with x and y coordinates for the legend or a quoted string. Default is "topright". See Details
horiz	logical. If TRUE, the legend will horizontal oriented
at.once	logical. If TRUE, all the variables are plot in separate windows at once
...	further options for function plot

Details

The leg.loc option may also be specified by setting one of the following quoted strings "bottomright", "bottom", "bottomleft", "left", "topleft", "top", "topright", "right", or "center". This places the legend on the inside of the plot frame at the given location with the orietation set by horiz. See [legend](#) for further details.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#)

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
plot(i)
```

predict.mtsdi

*Imputed Dataset Extraction***Description**

Extract imputed dataset from a mtsdi object

Usage

```
## S3 method for class 'mtsdi'
predict(object, ...)
```

Arguments

object imputation object
... further options passed to the generic function [predict](#)

Details

If log tranformation was used, dataset is back transformed accordingly.

Value

A vector of of rows mean with lenght n , where n is the number of observations.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

- Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. *Atmospheric Environment*, 102, 96-104.
- Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.
- McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.
- Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.
- Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also

[mnimput](#), [getmean](#), [edaprep](#)

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
predict(i)
```

```
print.mtsdi
```

Print Model Output

Description

Printing method for the imputation model

Usage

```
## S3 method for class 'mtsdi'
print(x, digits = getOption("digits"), ...)
```

Arguments

<code>x</code>	an object of class <code>summary.mtsdi</code>
<code>digits</code>	an integer indicating the decimal places. If not supplied, it is taken from options
<code>...</code>	further options passed to print

Value

This function does not return a value.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#)

Examples

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
print(i)
```

print.summary.mtsdi	<i>Print Summary</i>
---------------------	----------------------

Description

Printing method for the summary

Usage

```
## S3 method for class 'summary.mtsdi'  
print(x, digits = getOption("digits"), print.models = TRUE, ...)
```

Arguments

x	an object of class <code>summary.mtsdi</code>
print.models	a logical indicating that time filtering models should also be printed
digits	an integer indicating the decimal places. If not supplied, it is taken from options
...	further options passed from summary.mtsdi

Value

This function does not return a value.

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

See Also

[mnimput](#)

Examples

```
data(miss)  
f <- ~c31+c32+c33+c34+c35  
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))  
summary(i)
```

summary.mtsdi	<i>Summary Information</i>
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Description

Print summary information on the imputation object

Usage

```
## S3 method for class 'mtsdi'
summary(object, ...)
```

Arguments

object	an object of class mtsdi
...	further options passed to print.summary.mtsdi

Value

The function returns a list containing

call	function call
muhat	estimated mean vector
sigmahat	estimated covariance matrix
iterations	number of iterations used
convergence	relative difference of covariance determinant reached
time	time used in the process
models	details on the models used for time filtering
log	a logical indicating that data are log transformed
log.offset	offset used in the log transformation in order to avoid zeros

Author(s)

Washington Junger <wjunger@ims.uerj.br> and Antonio Ponce de Leon <ponce@ims.uerj.br>

References

Junger, W.L. and Ponce de Leon, A. (2015) Imputation of Missing Data in Time Series for Air Pollutants. *Atmospheric Environment*, 102, 96-104.

Johnson, R., Wichern, D. (1998) *Applied Multivariate Statistical Analysis*. Prentice Hall.

Dempster, A., Laird, N., Rubin, D. (1977) Maximum Likelihood from Incomplete Data via the Algorithm EM. *Journal of the Royal Statistical Society* 39(B)), 1–38.

McLachlan, G. J., Krishnan, T. (1997) *The EM algorithm and extensions*. John Wiley and Sons.

Box, G., Jenkins, G., Reinsel, G. (1994) *Time Series Analysis: Forecasting and Control*. 3 ed. Prentice Hall.

Hastie, T. J.; Tibshirani, R. J. (1990) *Generalized Additive Models*. Chapman and Hall.

See Also[mnimput](#), [predict](#)**Examples**

```
data(miss)
f <- ~c31+c32+c33+c34+c35
i <- mnimput(f,miss,eps=1e-3,ts=TRUE, method="spline",sp.control=list(df=c(7,7,7,7,7)))
summary(i)
```

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